SECULAR TREND OF IOWA PRECIPITATION

By CHARLES G. REED

[Weather Bureau, Des Moines, Iowa]

Before entering upon such a study as this, careful consideration must be given to the source and comparability of the data. One is always anxious to use a continuous record that extends back as far as possible. City rainfall records must be used with care, for they have usually been obtained in two or more locations, each on a higher building than its predecessor or surrounded by higher buildings. Records in the smaller towns are usually made by cooperative observers and very few are continuous and comparable for periods of more than 40 years. In a trend study, 40 years is scarcely long enough to make a good beginning, yet the layman equipped with only 40 years or so of more or less fickle memory, and little or no exact and comparable records, often expresses profound conclusions as to changes in climate and the multitude marvels at his wisdom. To the meteorologist, 100 years are but as a day.

In Iowa, or near its borders, extending back to 1873, there are nearly 200 rainfall records, varying from a few years to more than 50 years in length. Probably not one of these records could be regarded as ideal for a trend study, yet it seemed a pity not to utilize such a wealth of material in some such study, so an effort was made to determine precipitation trends on a basis of areas instead of stations.

Early in the seventies rainfall records were much more numerous per unit area in the northeastern counties than elsewhere in the State, but at the present time such records are more numerous in the northwestern portion. It is obvious that a straight average of the total number of reports would not be a true State average. The preponderance of stations in the rainier northeast portion of the State in the earlier years, compared with the present preponderance in the drier northwest portion, would produce an apparent but false downward trend in State averages. To correct this the State was divided into nine districts, of as nearly equal area as county boundaries would permit, and including about 11 counties in each, viz, northwest, north-central, northeast, west-central, central, east-central, southwest, south-central, and southeast. By considering all available data just outside the border as well as inside each district, it was possible to make satisfactory district averages of rainfall for each month for 53 years from 1875 to 1927. Data from adjoining States were included when very near the border of a district.

The trend of annual and seasonal State and district averages, thus refined, was calculated by the formula $I=\frac{\Sigma DY}{\Sigma Y^2}$ in which I is the annual increment (or decrement), D is the average rainfall of each year, and Y the number of each year, starting from the middle year, numbering up and down and prefixing a minus sign to all years before the middle year. The mean rainfall of the series is entered opposite the middle year and the annual increment or decrement added successively each way till the first and last years of the series are reached. The totals of precipitation at the end of each year represent points in a series of events, so the number of intervals between points is one less than the number of years. To cover the full period it is necessary to project the trend line backward through the first year of the series; so in practice, the annual increment, I, is multiplied by one more than the number of years preceding the middle year and the product added (algebraically, since I may be either positive or negative), to the mean of the whole series to get the value of the beginning of the trend line, on January 1 of the first year. With simple events, each of which does not represent an appreciable period of time, this amplification is not necessary.

For the 12 calendar months the annual decrease in rainfall for the State as a whole is −0.036354 inch, or 2 inches in 55 years. The annual averages and trend line for 55 years, 1873–1927, are shown on the accompanying graph. (Fig. 1.)

From an agricultural standpoint the trend in certain seasons might be important. For the summer months, June, July, and August combined, the annual decrement for the State as a whole is −0.034925 inch. (Fig. 1.) This is a total of 1.92 inches, or 15 per cent, in 55 years. Apparently an appreciable amount of rain has been transferred from summer to fall. About half of this decrease is made up by a total increase of 0.95 inch in the fall months, September, October, and November (fig. 1), when it is a positive detriment to the maturity and harvesting of Iowa's great corn crop. The spring seeding and planting months of March, April, and May show almost no change, amounting to an increase of only 0.06 inch in 55 years. (Fig. 2.) Winter precipitation (December, January, and February) shows a total decrease of 0.90 inch, or 39 per cent, in 55 years. (Fig. 2.) Reckoned in per cent, winter shows the largest relative decrease.

Southwest Iowa has had the largest actual decrease. In the nine counties of the southwest district the total decrease in 53 years is 3.41 inches, 10 per cent, or at the rate of 0.064321 inch per year. (Fig. 3.) As the district averages were rather weak in some districts in the years 1873 and 1874, these years were omitted from the district trend studies, though included in the State trends. The records of the Weather Bureau in Omaha had a marked effect on the trend in the southwest district, for they were continuous without a break through the 53-year period considered. The Council Bluffs records, just across the Missouri River from Omaha, also had a marked effect during the earlier years, when they were nearly unbroken. A trend calculation of the Omaha record shows a remarkable decrease of 0.262168 inch per year, or a total of 13.89 inches in 53 years, or 39 per cent. (Fig. 4.) The nearest station having a record useful for comparing trend is Weeping Water, Nebr., where, with a few interpolations, 51 years, 1878 to 1928, are available. Here the total decrease is 4.48 inches, 14 per cent, or at the rate of 0.087867 inch per year. For the State of Nebraska as a whole, in the 53 years, 1876–1928, the total decrease is 1.56 inches, 6 per cent, or 0.029439 inch per year.

The only station actually in the southwest district having a record warranting a trend calculation is Clarinda. Including interpolations recently made for use in the forthcoming revision of Hann's Climatology, for the years 1878 to 1887, inclusive, it is possible to make a 53-year trend, 1876–1928, inclusive, which shows an annual *increase* of 0.035030 inch, or a total *increase* of 1.86 inches, or 5.8 per cent, instead of a decrease.

Either there must be an area centering about Omaha where there is an abnormal long-time downward trend or else some sort of unfavorable conditions not readily apparent are developing and progressing in connection with the exposure of the rain gage. The rainfalls of the eighties were very heavy at Omaha, which gives the trend line a steep downward slope.

The averages for the west-central district were but slightly influenced by the Omaha records, yet the total decrease in that district in 53 years is 2.35 inches, 7 per cent, or about 0.044318 inch per year. Next stand the east-central and northeast districts, each with a

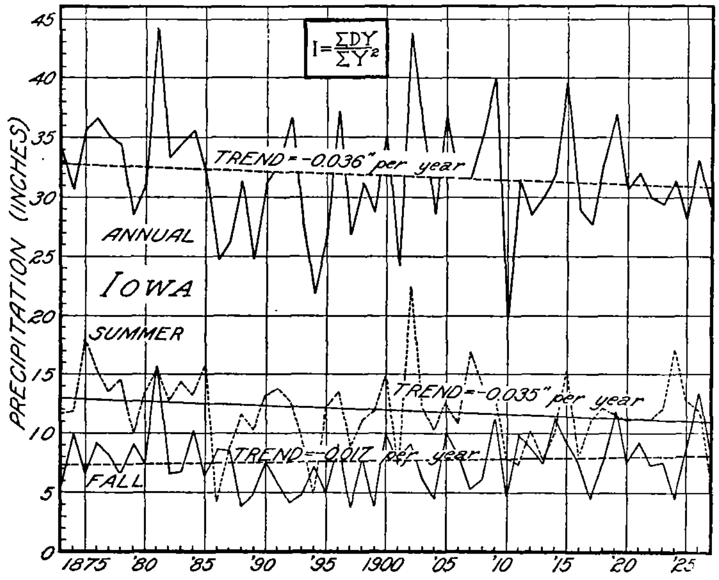

FIGURE 1.—Annual precipitation in Iowa has decreased at the rate of 0.036 inch per year for 55 years. Summer rainfall has noticeably decreased or been partly transferred over into the fall months

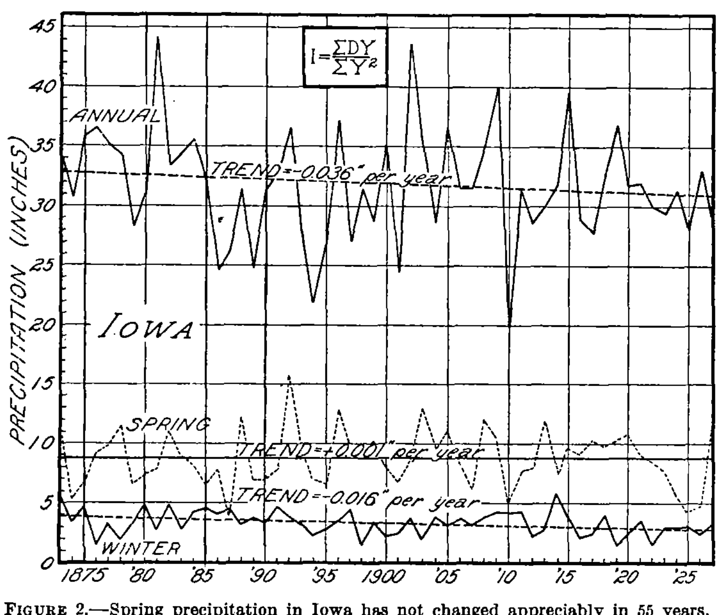

FIGURE 2.—Spring precipitation in Iowa has not changed appreciably in 55 years, but winter precipitation has decreased 39 per cent

decrease of 2.29 inches. At Independence, Buchanan County, in the northeast district, the total decrease in rainfall is 4.66 inches, or 14 per cent, in 59 years, 1869–1927. This is at the rate of 0.07915 inch per year. At Dubuque, Dubuque County, also in the northeast district, the total decrease is 4.89 inches, or 14 per cent, in 77 years. This is at the rate of about 0.063550 inch per year. The least decrease is in the northwest district, where it amounts to only 0.20 inch. Algona, Kossuth County, near the middle of the northern boundary of the State, shows not a decrease but a total increase of 0.21 inch in 55 years, in spite of the claim that drainage of northern Iowa land has reduced the rainfall. In fact, this study shows the greatest decrease in rainfall is in the southwest district where there has been the least drainage of land. State-wide records in Minnesota are not of sufficient length to be comparable with Iowa data, but the total increase in rainfall at Fort Snelling and St. Paul is 1.19 inches in 91 years, 1837–1927, and

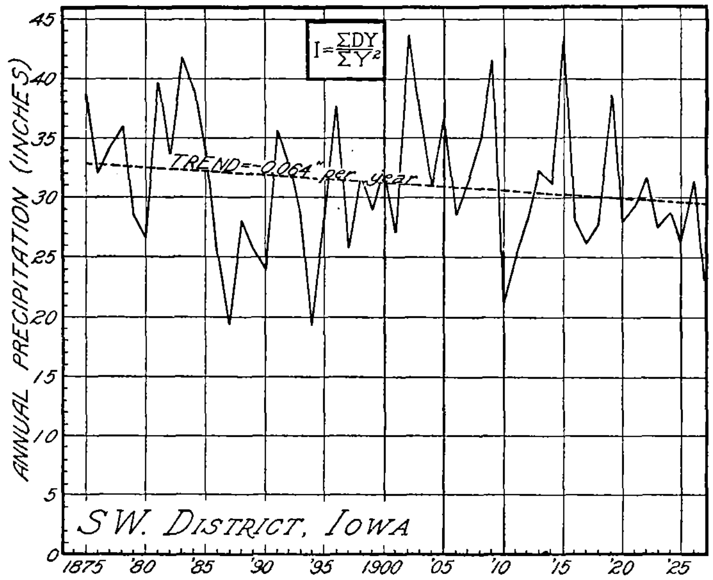

FIGURE 3.—The greatest decrease in Iowa precipitation is in the southwest district where it amounts to 3.41 inches in 53 years

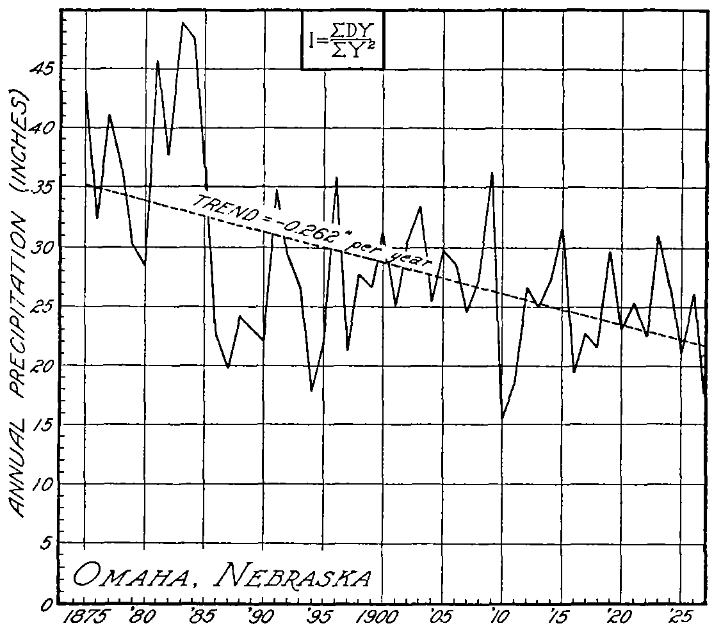

FIGURE 4.—The greatest decrease in the region is centered at Omaha where it amounts to 13.89 inches or 39 per cent in 53 years

it seems probable that the general trend of Minnesota rainfall is upward. The distribution of the total decrease in precipitation in 53 years by districts in Iowa is shown on the accompanying map. (Fig. 5.)

The trend by districts for the three principal crop months, June, July, and August combined, is shown on the accompanying map. (Fig. 6.) Here again the largest decrease is in the southwest district, where it is 3.34 inches, or 23 per cent, and almost the same as for

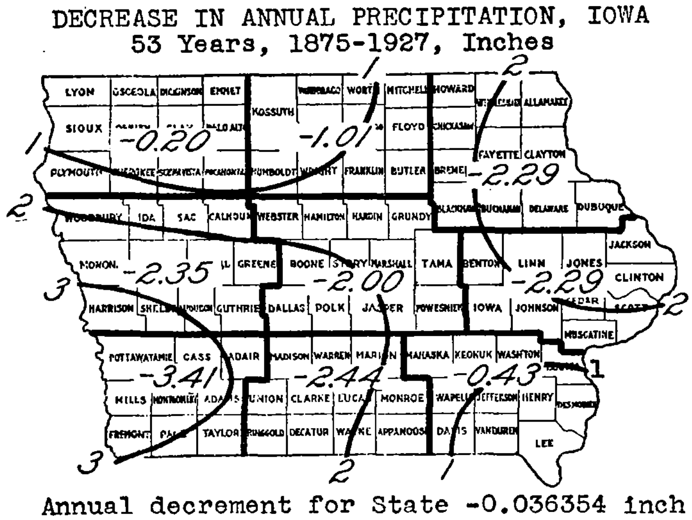

FIGURE 5.—Iowa precipitation has decreased markedly from southwest to northeast, but very slightly in the northwest district

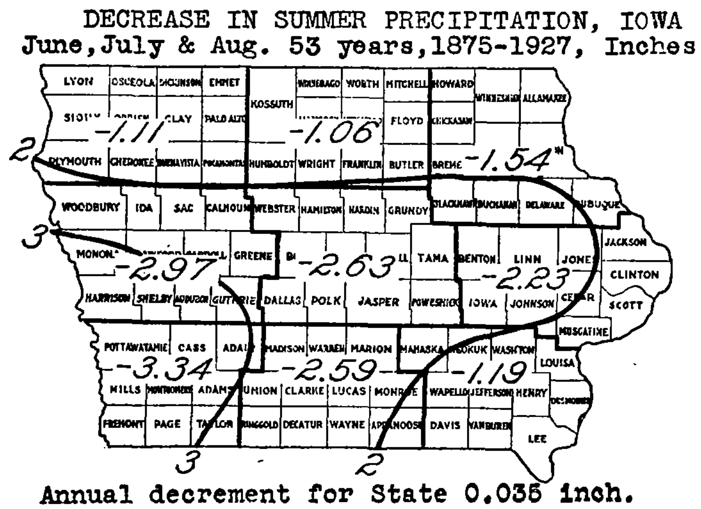

FIGURE 6.—Summer precipitation in Iowa has decreased decidedly in the southwest and west-central districts, around which the decrease diminishes in regular zones

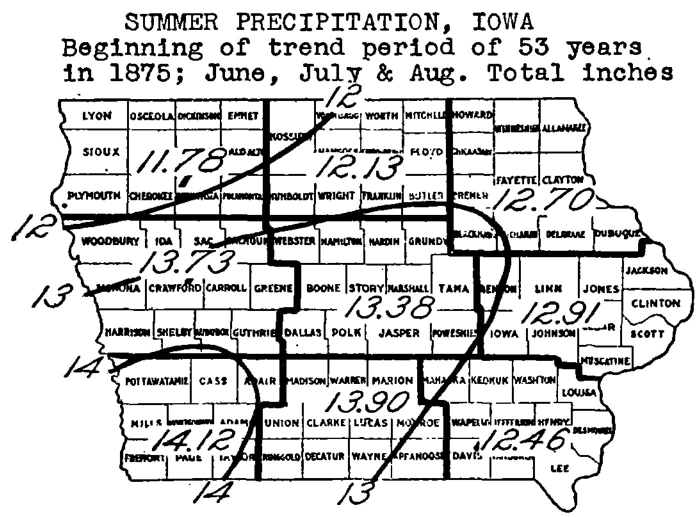

FIGURE 7.—Southwest Iowa had much superfluous summer rainfall 53 [years ago]

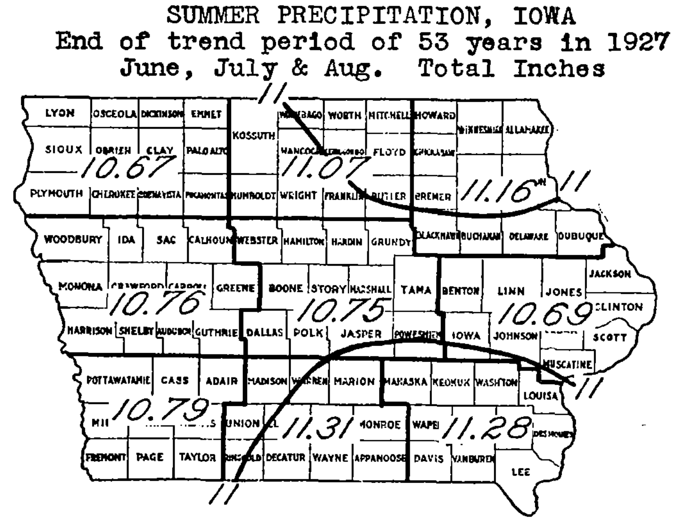

FIGURE 8.—After 53 years, the present distribution of Iowa summer rainfall has settled down to what appears to be a normal, stable, distribution over the State

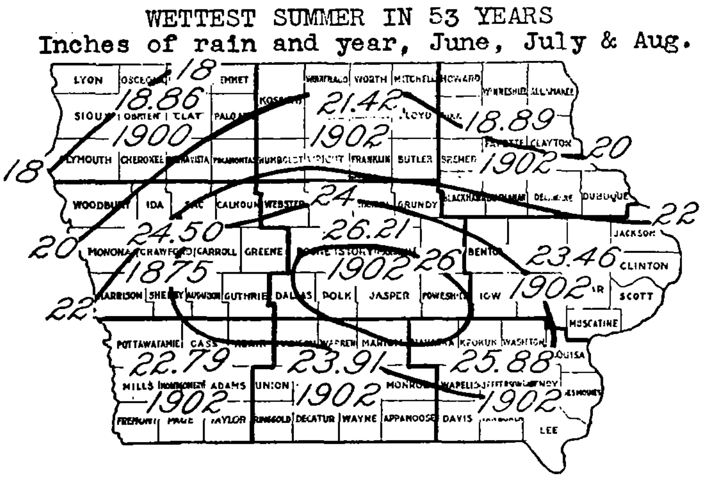

FIGURE 9.—The central district holds the record for wettest summer, which occurred in 1902

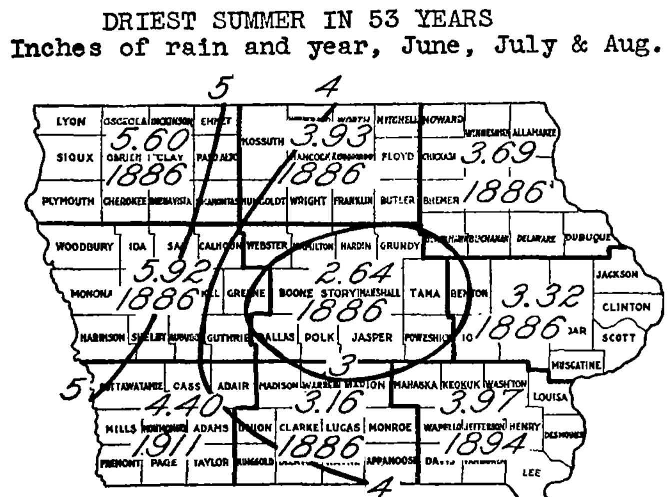

FIGURE 10.—Also the central district holds the record for driest summer, which occurred in 1886

the entire year. Next is the west-central district, with a decrease of 2.97 inches, which coincides with the impressions of farmers who have farmed in that district for a lifetime and who furnished part of the inspiration for this study. The least decrease in summer rainfall is in the north-central district, 1.06 inches.

The values of the ends of the trend lines of the nine districts were entered on maps to show just how the summer precipitation of 53 years ago would compare with that of 1927. These are shown by maps. (Figs. 7 and 8.) Note the center of heavy rainfall 53 years ago in the southwest and the area of relatively heavy rainfall extending northeast beyond the center of the State. Note also that at the end of the period the differences have become leveled down so that there is now a range of only 0.64 inch between the driest northwest district and the wettest south-central district, while 53 years ago the range was 2.34 inches between the driest northwest district and the wettest southwest district.

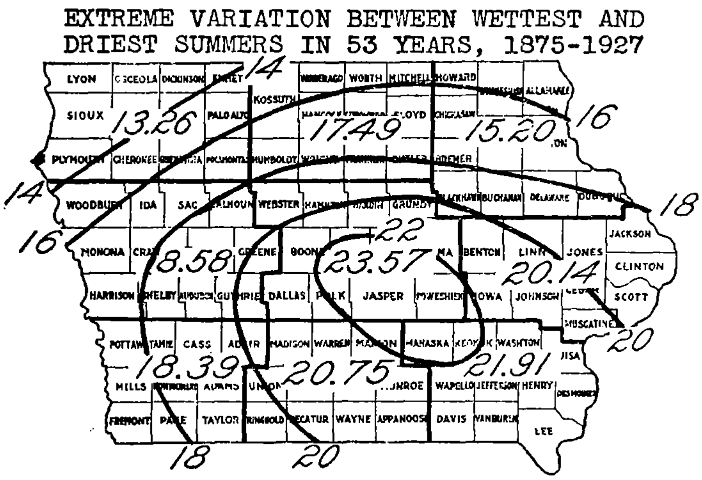

FIGURE 11.—The central district shows the most extreme variation in summer rainfall while the northwest district is most constant

Corn, if affected at all by this decrease in summer rainfall, has been benefited, or possibly improved farming has more than overcome any adverse effects, for the trend in corn yield per acre has been upward in all districts for 40 years, though the improvement in corn has been least in the southwest and south-central districts, where it amounts to only a gain of 0.18 bushel per acre per year. The greatest concentration of acres of corn per unit area is in the western districts, so there was evidently much superfluous rainfall in the earlier years.

The record wet summer was 1902 in all districts, except the west-central, where the summer of 1875 was the wettest, and the northwest, where the summer of 1900 was the wettest; and the wettest district was the central in 1902 with 26.21 inches. (Fig. 9.) The record dry summer was 1886 in all but the southwest district, where the driest was 1911, with 4.40 inches, and the southeast, where the driest was 1894, with 3.97 inches; and the driest district was the central in 1886, with 2.64 inches. (Fig. 10.) In extreme variation of summer rainfall the central district leads with a range of 26.21 inches, and the northwest district is least with 13.26 inches. (Fig. 11.) This small variation in rainfall, combined with a drouth-resistant soil, explains the dependability of the northwest district in corn production. At the end of the trend period in 1927 the northwest district has 38 per cent of its annual rainfall in the summer, leading in this feature over all the other districts, while the east-central district has the least, 33 per cent. At the beginning of the period the west-central district led with 44 per cent, and the east-central and southeast were least with 37 per cent.

SUMMARY

Iowa is becoming steadily drier, but up to this time the tendency has not proceeded far enough to threaten its principal crop, corn; in fact, conditions for corn seem to be improving. There is, no doubt, a limit, but probably the trend will change before the danger line for corn is reached.

ALIGNMENT DIAGRAM FOR "R" OF THE ENERGY-EVAPORATION EQUATION

By N. W. CUMMINGS

[Scripps Institution of Oceanography of the University of California, La Jolla, Calif.]

The evaporation from an open-water surface is determined by the relation (see Cummings and Richardson, 1927).

$$E=\frac{I-B-S-C}{L(1+R)} \tag{1}$$

where (E) is the evaporation in centimeters of depth, during any arbitrary time, (I) is the energy which the sun and sky deliver to 1 square centimeter of the water surface during the same interval of time; (S) is the energy which accumulates during this time in a column of water having an area of 1 square centimeter and a depth equal to the average depth of the water body, while (C) takes care of certain corrections which are usually small. (L) is the latent heat of water and (R) is the ratio of sensible heat swept away by the wind to latent heat carried off by the vapor. Bowen (1926) shows that (R) can be calculated by means of the equation

$$R=.46\frac{T_w-T_a}{P_w-P_a}\frac{B}{760} \tag{2}$$

where (T_w) is the temperature of the water surface, (T_a) that of the dry bulb, (P_w) the pressure of saturated water vapor at temperature (T_w), while (P_a) is the absolute humidity in millimeters of mercury, and (B) is the barometric pressure.

In order to facilitate numerical applications an alignment diagram was constructed by the following method:

Assuming $B=760$ the equation may be written in the determinant form

$$\begin{vmatrix} 1 & R & 0 \\ P_a & .46T_a & 1 \\ P_w & .46T_w & 1 \end{vmatrix}=0 \tag{3}$$

Making use of the fact that the elements of any row or column can be added to the element of any other row or column without changing the value of the determinant, we add the elements of the first column to those of the last, obtaining

$$\begin{vmatrix} 1 & R & 1 \\ P_a & .46T_a & 1+P_a \\ P_w & .46T_w & 1+P_w \end{vmatrix}=0 \tag{4}$$

Making use of the further fact that the effect of multiplying or dividing all the elements of any column or row by the same number is to multiply or divide the determinant